Physica A 466 (2017) 450–454

Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

Lindbladian operators, von Neumann entropy and energy conservation in time-dependent quantum open systems

Congjie Ou [a], Ralph V. Chamberlin [b], Sumiyoshi Abe [a,c,d,*]

[a] College of Information Science and Engineering, Huaqiao University, Xiamen, 361021, China
[b] Department of Physics, Arizona State University, Tempe, AZ 85287-1504, USA
[c] Department of Physical Engineering, Mie University, Mie 514-8507, Japan
[d] Institute of Physics, Kazan Federal University, Kazan 420008, Russia

HIGHLIGHTS

- Time-dependent quantum open systems are discussed based on the Lindblad equation.
- The condition is derived for the internal energy to be conserved in time.
- The harmonic oscillator with the time-dependent frequency is studied as an example.
- The corresponding Lindbladian operators are determined.
- The von Neumann entropy is shown not to decrease in time.

ARTICLE INFO

Article history:
Received 22 May 2016
Received in revised form 23 August 2016
Available online 22 September 2016

Keywords:
Quantum dissipative systems
Lindblad equation
Conservation of internal energy
von Neumann entropy

ABSTRACT

The Lindblad equation is widely employed in studies of Markovian quantum open systems. Here, the following question is posed: in a quantum open system with a time-dependent Hamiltonian such as a subsystem in contact with the heat bath, what is the corresponding Lindblad equation for the quantum state that keeps the internal energy of the subsystem constant in time? This issue is of importance in realizing quasi-stationary states of open systems such as quantum circuits and batteries. As an illustrative example, the time-dependent harmonic oscillator is analyzed. It is shown that the Lindbladian operator is uniquely determined with the help of a Lie-algebraic structure, and the time derivative of the von Neumann entropy is shown to be nonnegative if the curvature of the harmonic potential monotonically decreases in time.

1. Introduction

Quantum open systems have long been attracting particular attention in connection with a variety of problems such as errors in quantum computation, measurements, decoherence for micro–macro transition, and foundations of statistical mechanics. Accordingly, a lot of effort has been devoted to the study of nonunitary quantum subdynamics. The standard approach is to consider an isolated multipartite system governed by unitary dynamics with given interactions, to identify an objective subsystem, and then to eliminate the remaining environmental degrees of freedom to obtain the subdynamics of the objective subsystem. In cases where interaction and entanglement between the objective subsystem and its environment

* Corresponding author at: Department of Physical Engineering, Mie University, Mie 514-8507, Japan.
E-mail address: suabe@sf6.so-net.ne.jp (S. Abe).

http://dx.doi.org/10.1016/j.physa.2016.09.016
0378-4371/